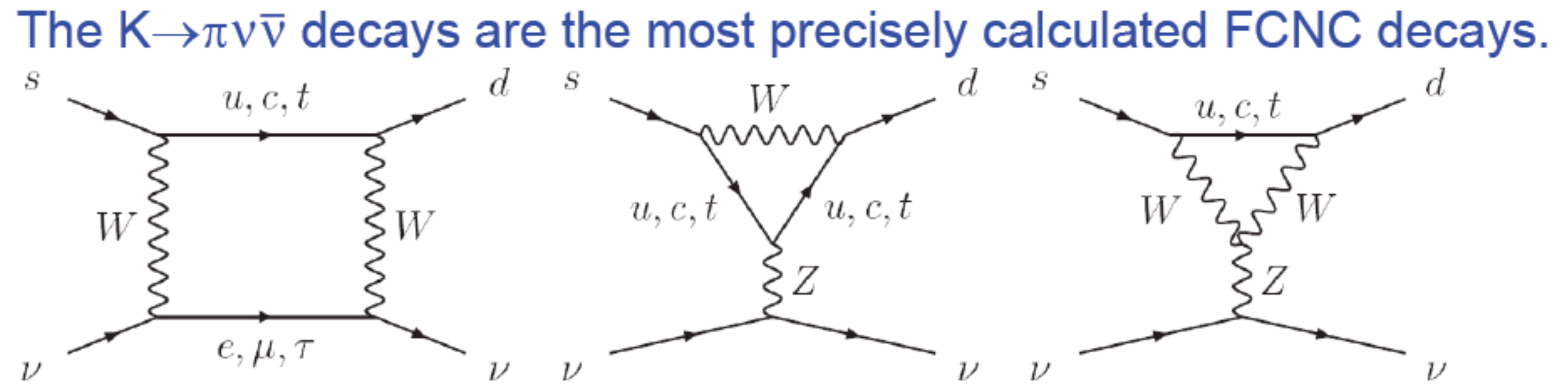
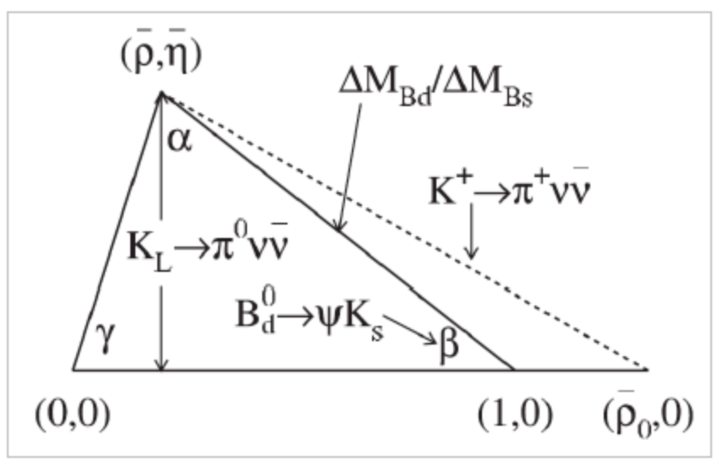
Measurement of the $K^+ \to \pi^+ \nu\bar{\nu}$ Decay at Fermilab

$K^+ \to \pi^+ \nu\bar{\nu}$ in the Standard Model

The $K \to \pi\nu\bar{\nu}$ decays are the most precisely calculated FCNC decays.





- A single effective operator $(\bar{s}_L\gamma^\mu d_L)(\bar{\nu}_L\gamma_\mu\nu_L)$
- Dominated by top quark (charm significant, but controlled)
- Hadronic matrix element shared with $K \to \pi e\nu$
- Largest uncertainty from CKM elements (which will improve)

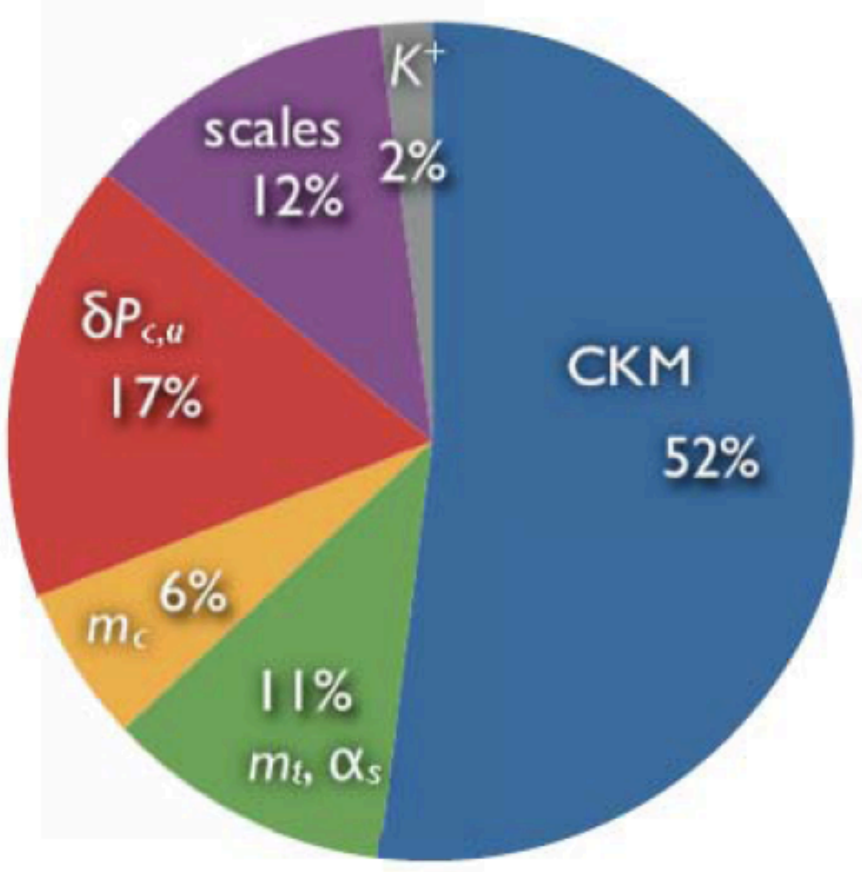
$B_{SM}(K^+ \to \pi^+\nu\bar{\nu}) = (8.5 \pm 0.7) \times 10^{-11}$

Brod and Gorbahn, PRD 78, 034006(2008)

- Remains clean in New Physics models

Summary of SM Theory Uncertainties

CKM parameter uncertainties dominate the error budget today.



With foreseeable improvements, it is reasonable to expect the total SM theory error ≤6%.

A. Kronfeld analysis

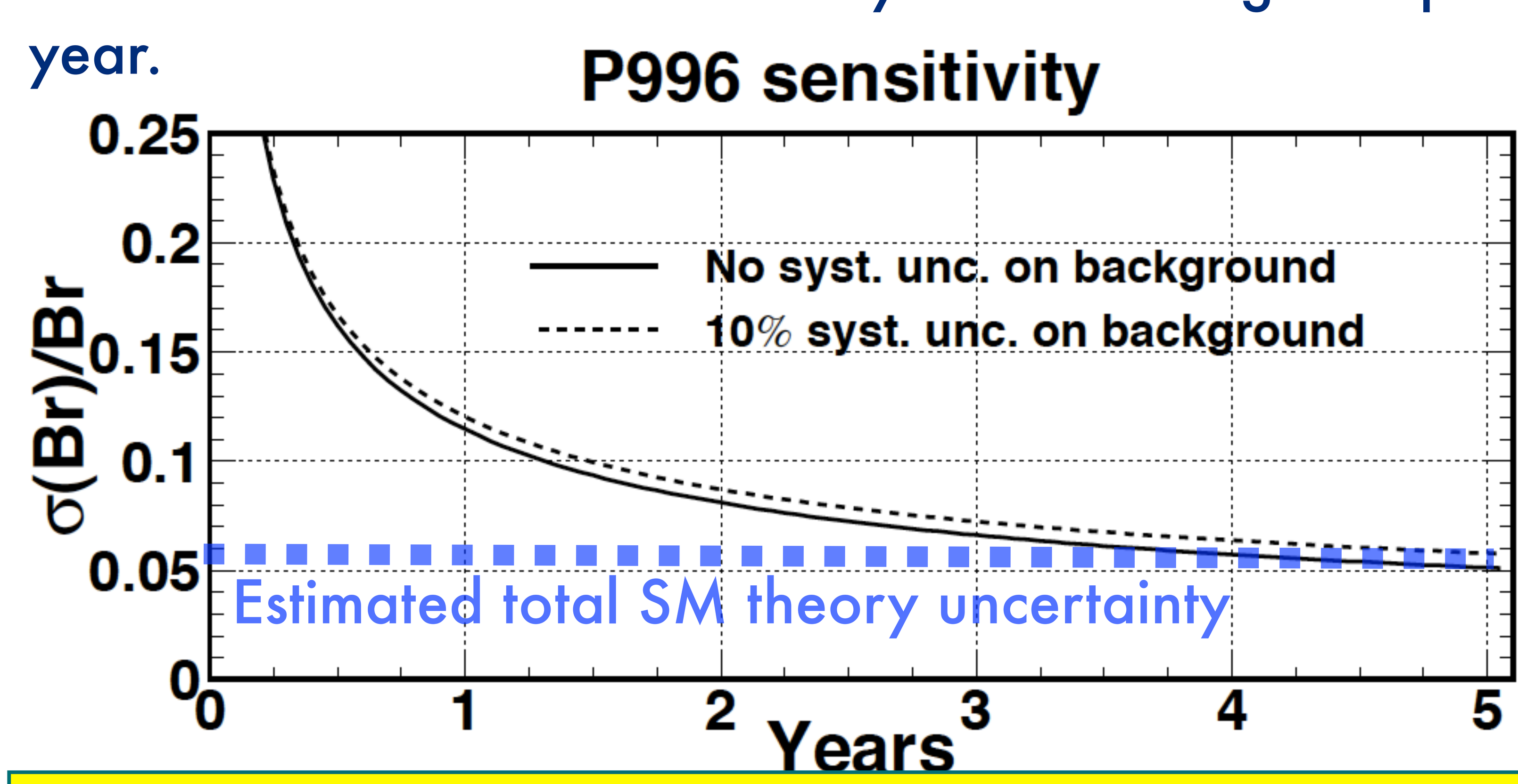
Unmatched by any other FCNC process (K or B).

30% deviation from the SM would be a 5σ signal of NP

SM theory error for $K_L \to \pi^0\nu\bar{\nu}$ mode is no longer smaller.

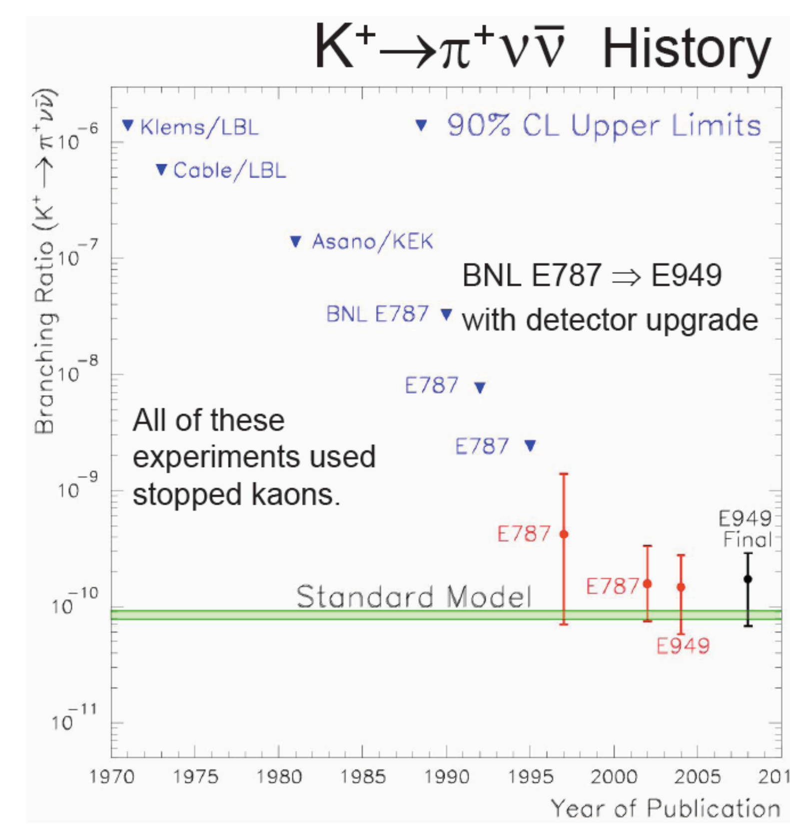
U. Haisch, arXiv:0707.3098

The fourth generation experiment, P996, would detect about 200 Kpnn decays per year by exploiting incremental improvements over E949, a high duty factor utilizing the Tevatron as a "Stretcher" and by more running time per year.



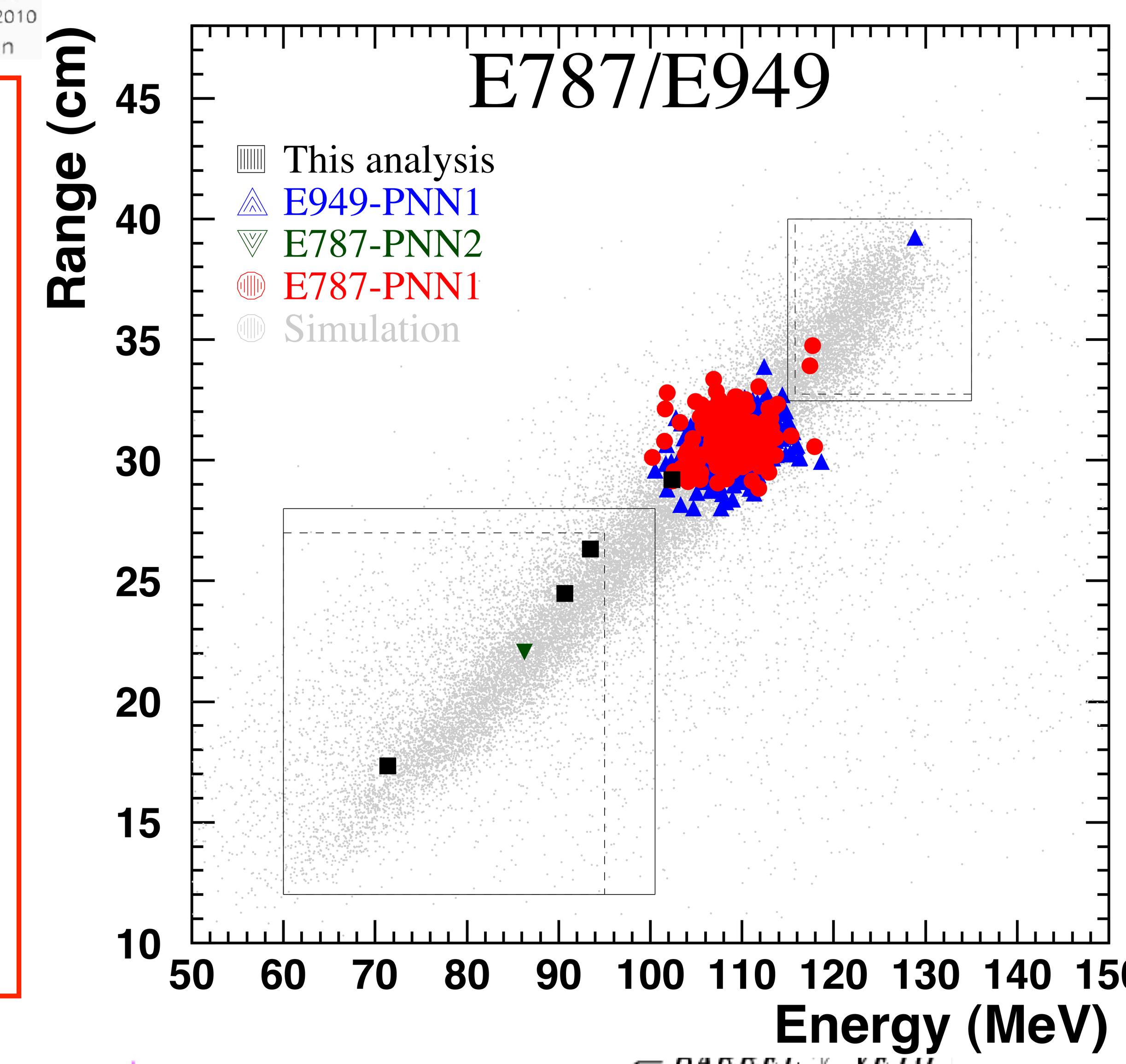
A precision of <5% could be achieved in 3-5 years if the branching ratio is consistent with the SM expectation.

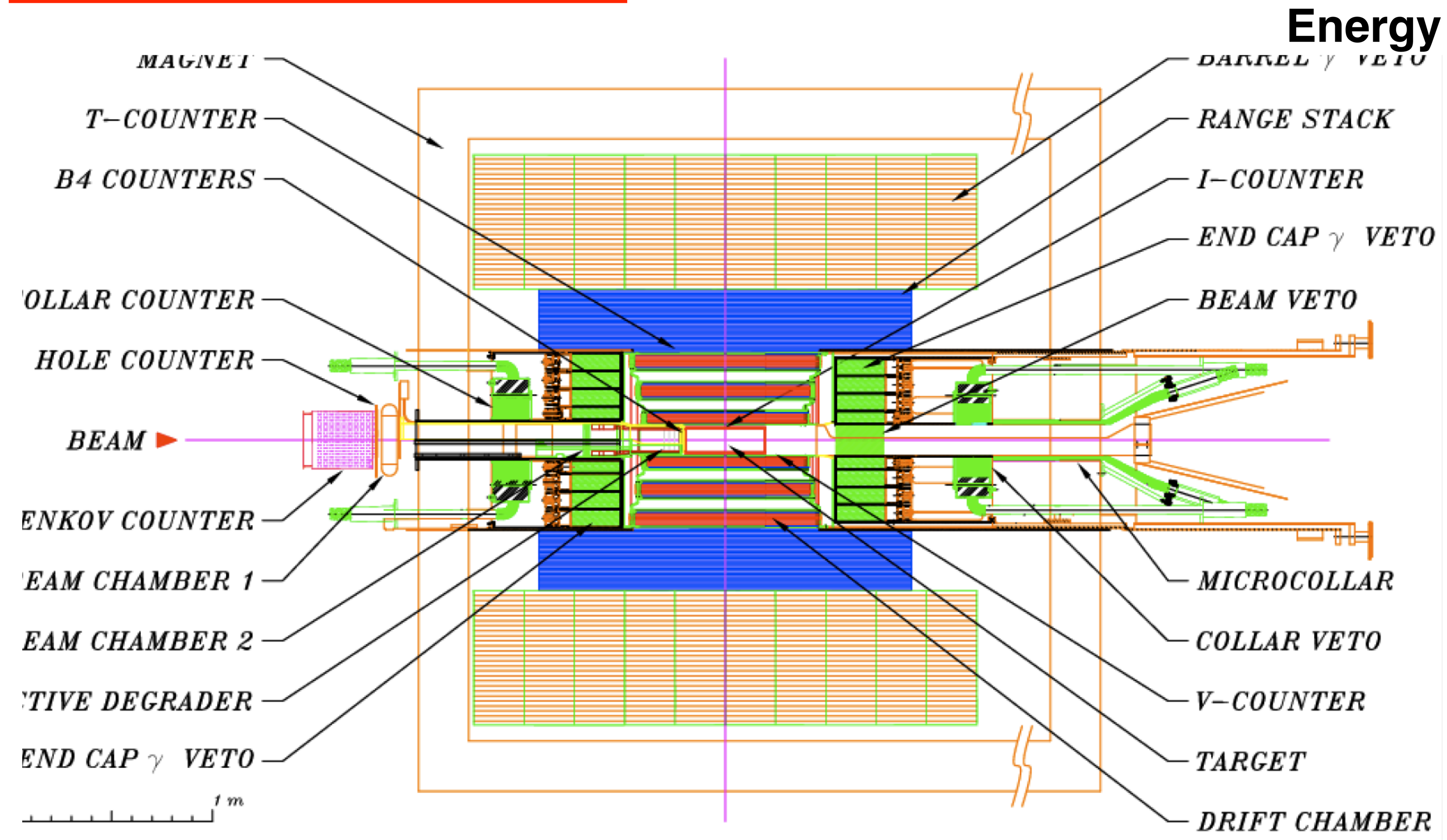
Observation of $K^+ \to \pi^+\nu\nu$ with a 10^{-10} branching ratio is experimentally challenging. The signature is a charged kaon followed by a charged pion with no other observed particles. Backgrounds from $K^+ \to \pi^+\pi^0$ and $K^+ \to \mu^+\nu$ involve branching ratios ten orders of magnitude larger. The experimental strategy is to prove that candidate events have a low probability of being due to background. Successful $K^+ \to \pi^+\nu\nu$ detection requires powerful π^+ particle identification, high- efficiency, 4π sr photon veto capability and efficient K^+ identification to eliminate beam-related background.



Over 2 decades, BNL experiments E787 and E949 refined the technique for $K^+ \to \pi^+\nu\nu$ detection using stopped kaons in 3 experimental generations to observe 7 $K^+ \to \pi^+\nu\nu$ candidates resulting in $B(K^+ \to \pi^+\nu\nu) = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$.

Measured range in plastic scintillator vs kinetic energy for all $K^+ \to \pi^+\nu\nu$ candidates in E787 & E949. The solid and dashed lines indicate the signal regions. The grey points are from signal MC. The cluster of points near 180 MeV is due to $K^+ \to \pi^+\pi^0$ events surviving the photon veto.





Proposed P996 detector.

A 550 MeV/c K+ are stopped in a highly segmented active target. $K^+ \to \pi^+\nu\nu$ decays are observed with a precision, low-mass central drift chamber surrounded by segmented scintillation detectors to measure pion range, energy and the π-μ-e decay sequence and enclosed by efficient 4π sr EM calorimeter for vetoing events accompanied by photons.

Member institutions of the P996 collaboration are Arizona State University(USA), Brookhaven National Laboratory(USA), Fermilab(USA), Institute for Nuclear Research(Russia), Instituto Nazionale di Fisica Nucleare, Pisa (Italy), TRIUMF(Canada), University of British Columbia(Canada), University of Texas at Austin(USA), University of Illinois, Urbana(USA), University of Northern British Columbia (Canada), Universidad Autonoma de San Luis Potosi(Mexico), Tsinghua University, Beijing(China)